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BRIEFING BY NATIONAL BUREAU OF STANDARDS

REPORT

OF THE

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., August 4, 1959.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics.

DEAR MR. CHAIRMAN: I am forwarding herewith for committee consideration a report on "Briefing by National Bureau of Standards" prepared by John A. Carstarphen, Jr., counsel for the investigations subcommittee.

This report is based on testimony of qualified witnesses in open hearings and on personal observation of the Washington installations by a subcommittee of the full committee.

It is hoped that this report will stimulate the interest of the lay public and that they, in turn, will become better acquainted with the purposes of the National Bureau of Standards.

CHARLES F. DUCANDER,
Executive Director and Chief Counsel.

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BRIEFING BY NATIONAL BUREAU OF STANDARDS

I. INTRODUCTION

Under the provisions of House Resolution 580 of the 85th Congress, which established the Committee on Science and Astronautics, the National Bureau of Standards is one of four named agencies over which the committee is given legislative jurisdiction. The committee, in order to familiarize itself with the work of the Bureau of Standards and its personnel, held hearings on May 7, 8, and 21, 1959. Also a special subcommittee conducted a field trip to the Bureau of Standards installation in Washington, and also a visit to the prospective new location near Gaithersburg, Md. The purpose of these hearings was to acquaint the committee members with the general functions of the Bureau and the responsibilities of the various scientific divisions, including the various technical staff offices. Considering that the committee was newly created, and the placement of this agency, an integral part of the Department of Commerce, under the jurisdiction of the committee, it was felt that a briefing with regard to the functions and the responsibilities of the Bureau would be in the best interests of a better legislative relationship between the committee and the Bureau.

II. HISTORICAL BACKGROUND

The National Bureau of Standards, established by the act of March 3, 1901 (31 Stat. 1449; 15 U.S.C. 271), is a primary organizational unit within and under the jurisdiction of the Department of Commerce. The Bureau is headed by a Director, appointed by the President by and with the advice and consent of the Senate, who is immediately responsible to the Under Secretary of Commerce.

Pursuant to the authority vested in the Secretary of Commerce by Reorganization Plan No. 5 of 1950, the Director of the Bureau of Standards is authorized to perform the functions and exercise the authority vested in the Secretary of Commerce by title 15, chapters 6 and 7, United States Code, with respect to physical science activities within the special competence of the National Bureau of Standards.

The Director has authority to redelegate such authority as he deems appropriate, prescribing the limitations, restrictions, and conditions in the exercise of such authority by employees of the Bureau with respect to the functions within the special competence of the Bureau. The organizational setup of the National Bureau of Standards is comprised of 12 scientific divisions at the headquarters in Washington reporting to the Director through Associate Directors as may be assigned. There are five scientific divisions located at the Boulder Laboratories reporting to the Associate Director for said Boulder Laboratories. The Bureau also consists of four technical staff offices. There are likewise nine divisions which report to the Associate Director for Administration.

III. GENERAL FUNCTIONS OF THE NATIONAL BUREAU OF STANDARDS

The basic functions of the National Bureau of Standards are (*a*) development and maintenance of the national standards of measurement, and the provision of means for making measurements consistent with those standards; (*b*) determination of physical constants and properties of materials; (*c*) development of methods for testing materials, mechanisms, and structures, and the making of such tests as may be necessary, particularly for Government agencies; (*d*) cooperation in the establishment of standard practices incorporated in codes and specifications; (*e*) advisory services to Government agencies on scientific and technical problems; and (*f*) invention and development of devices to serve special needs of the Government.

Generally speaking, the general functions of the Bureau are of two categories: (1) to provide for the country a central basis for a system of uniform measurement for science and industry, and (2) the operation of central technical service facilities in designated areas of science and technology in cooperation with other Government agencies. The responsibilities, as prescribed by statute, have been basically unchanged since the creation of the Bureau in 1901. However, the scope and complexity of the work has changed considerably over this period of 58 years. As languages are a means of communication between individuals, so is a standard of physical measurement a means of communication of scientific and technical information among scientists and engineers. Scientific and engineering endeavor is concerned with efforts to measure properties of things which, in turn, must be expressed in numbers and the numbers must be referred to a standard in order that they will have meaning from one laboratory to another.

The whole of commerce concerns itself with the exchange of goods, which obviously requires agreement as to the amount or number exchanged, and in order for an orderly exchange to be brought about the amount or number must of necessity be referred to a standard. This interchangeability has assumed increased importance in our economy, particularly within the past 50 years, because of the very ready requirement of immediate interchangeability of parts. Our tremendous system of mass production is based on the ability to fabricate a part so that it will conform to a predetermined physical characteristic or a number or a fixed amount. To assure that the parts meet these required characteristics, the measurement techniques and standards to which they may be referred must be of a high order of accuracy to allow the mass production of our industry to function properly. The interchangeability of information among scientists and engineers, the exchange of goods in commerce, and the interchangeability of component parts for mass production in industry, are really based on a standard for physical measurement.

The second general category of the above-listed functions of the Bureau, is the scientific and technical assistance rendered to other Government agencies. Such assistance may be found in four general areas, as follows: (1) radio propagation; (2) electronic computing devices; (3) building technology and fire research, and (4) cryogenic engineering.

Radio propagation

The Central Radio Propagation Laboratory of the Bureau acts to accumulate, analyze, and disseminate information on the properties of the earth's atmosphere which affect the transmission of radio waves.

This Laboratory likewise does extensive research. They have effected long-range radio communications and played a very important role in that they were assigned a major responsibility for the IGY observations upon the ionosphere.

See appendix I for discussion of relationship of CRPL program to space communications and space research.

Electronic computing devices

This program had its beginning as a result of developments in World War II and started with a request from the Census Bureau to assist in seeing if the World War II advances in electronic techniques could be developed where they would assist the Census Bureau in the processing of data. This development assistance of the Bureau led to design contract study, and subsequent procurement contracts which ultimately resulted in the first three Univacs produced. The Bureau built a machine of its own to provide internal assistance and applied these modern computer tools to the solution of other technical problems. The Bureau now has a rather extensive program of providing assistance to other agencies of Government in the utilization of these techniques. The Bureau secured funds a few years ago to construct a large-scale pilot data processing machine which, it is hoped, will be completed this year, and which will be used to make pilot studies on data-computing problems of Government agencies.

See appendix II for further information on data computing systems.

Building technology and fire research

This program is many years old. It seeks to develop information on the properties of building materials and structural techniques, and to assist other Government agencies in applying this information to their advantage in carrying out their construction responsibilities. The data here available are likewise of considerable importance to the general public, and a number of publications issued by the Bureau in this area are widely used by the construction industry. One of the first instances of this particular phase of work occurred more than 50 years ago when the Bureau rendered assistance on building materials that went into the House Office Building. They also made an investigation and examination of the cables for use in the Washington Monument.

See appendix III for details on building technology and fire research programs.

Cryogenic engineering

The fourth service area is that of cryogenic engineering which originated approximately 9 years ago in response to a request from the Atomic Energy Commission in connection with its problems in handling and utilizing liquid hydrogen. This facility is located at the Boulder laboratories. One of the more interesting aspects of this program has been the development of the Dewar flask, a specially insulated device for transporting helium in liquid form.

See appendix IV for details on cryogenic engineering.

IV. FACILITIES OF THE NATIONAL BUREAU OF STANDARDS

A major problem encountered by the Bureau in recent years in connection with the performance of its basic responsibilities relates

to the physical plant. The laboratories and administrative offices in Washington are at the present time housed in 94 buildings on a 68-acre tract located in the center of residential Northwest Washington. This site has been occupied by the Bureau since 1903. Of the aforesaid 94 buildings, 31 are of permanent construction, 30 semipermanent, and 33 temporary. Many of these buildings are outmoded and inefficient for modern research laboratory use, and expensive to maintain. Many of the temporary and semipermanent buildings were built during emergency periods and were hastily constructed. If the Bureau were not to be relocated, many of these buildings would require replacement during the next few years. The Bureau has also faced very serious difficulties with respect to utilities, laboratory services, electrical distribution system, and mechanical facilities for laboratories during recent years. It has not been possible to correct the basic deficiencies. The utilities are inadequate and because of the continual growth and electrical load required in the equipment needs of modern research, the problem has been greatly aggravated. It is felt that one of the limiting factors with respect to new programs is the heavy utility requirement that cannot be met at the present installation.

Unfortunately many of the closely related research activities, presently, are being housed in widely separated locations. This makes difficult effective management. One scientific division has space in 17 different buildings, and the average technical division is housed in 8 different buildings. Such dispersal results not only in difficulties of supervision and coordination of project work, but also in loss of effective interchange among related projects as well. It is impracticable to regroup many of the activities at the present site, as it would not justify the very large expenditure for complete regrouping. The inadequacy of many of the present buildings would perhaps lead to less adequate facilities than new programs presently have.

In 1955 the Bureau initiated a plan for a large relocation program. Accordingly, in 1957 a 550-acre site was acquired for new laboratories. This new site is located at the Gaithersburg interchange of new U.S. Route 240, 20 miles from the center of Washington. In 1959 an appropriation was secured to undertake design and engineering for the new facilities. The facilities which are now being designed as a result of primary studies have as their objective the provision of modern laboratories commensurate with the Bureau's responsibility to the scientific and industrial community. The major buildings are to be constructed on a modular basis and will utilize movable partitions. It is hoped that this will provide the flexibility and adaptability of space element which will provide maximum utility, efficiency, and operating economy and will provide the type of facilities which can best meet the needs of modern research programs. The facility will consolidate the widely scattered component parts of the Bureau's programs into the smallest practicable number of buildings. This will not only permit the initial assignment of space on the basis of close program relationships, but will also facilitate the subsequent reassignment of space as the program relationships change.

One very important feature of the new facilities is that it will provide adequate facilities for new programs which cannot be adequately undertaken with existing facilities. For example, a high intensity electronic accelerator is urgently needed to provide standards of measurement and data for Government installations which are

beginning to use radiation as a processing or analytical tool. This proposed accelerator would produce electronic beams with energies greater than 40 million electronic volts and power output greater than 40 kilowatts. This would provide electronic beam power from several hundred thousand to a million times the power presently available from equipment at the present Bureau site.

A second major requirement for which there is a critical need relates to the Bureau's large capacity force standards. The Bureau's present deadweight machine has a maximum capacity of 111,000 pounds. The large-scale rocket and missile program has focused attention on the inadequacies of the Bureau's ability to calibrate these devices. To meet the very critical need in this area, the Bureau is preparing to include at the Gaithersburg facility a 300,000-pound and a 1-million-pound capacity deadweight machine.

Another new facility for which the need has grown steadily over the past few years is a nuclear research reactor. This tool would provide new techniques for studying the fundamental properties of matter and would enable the Bureau to enter into the study of high-intensity neutron flux standards, which they are unable to do at present.

It should be called to attention that the headquarters facility in Washington, D.C., is not the only new facility of the Bureau, for they are in the process of acquiring five new field sites for the radio propagation program.

V. INTERNATIONAL ASPECTS OF THE NATIONAL BUREAU OF STANDARDS

Because of the very nature of the work of the Bureau of Standards, the Bureau has established many contacts with other countries. Some of these are on an organizational basis and others are on a personal or individual basis. An example of the former is the International Bureau of Weights and Measures. There are a number of international scientific unions such as the Scientific Radio Union, and the International Union of Chemistry. These international unions have periodic meetings at intervals of 2 or 3 years. The Bureau recently has hosted two such meetings. One was the International Scientific Radio meeting held at Boulder Laboratory in 1957, another was the meeting of the International Commission for Uniform Methods of Sugar Analysis. Still another was the scientific organization known as the International Council of Scientific Unions. Another aspect of foreign cooperation is found in the individual or personal relationships. In 1958, the Bureau entertained approximately 1,000 visitors, from some 50 countries. Of these, 285 came as teams (of which there were 27) sponsored by the International Cooperation Administration of the State Department, and the remaining 700 came as individuals or in groups of 2 or more. In addition, the Bureau exchanges scientific publications with similar publications in other countries. There are currently some 521 exchanges with 46 countries. The Bureau plays an important part in the training of guest workers, which is a training system sponsored by the International Cooperation Administration and the United Nations. In 1959 the Bureau had eight such trainees. In the last fiscal year some 40,000 specimens of standard material were sold by the Bureau, of which approximately 10,000 went to foreign countries.

VI. PUBLICATIONS OF THE NATIONAL BUREAU OF STANDARDS

The major publication of the Bureau of Standards is the Journal of Research, which is a monthly scientific publication giving tables of technical data and papers describing the results of Bureau research. Shortly, the Bureau plans to extend this publication into four sections, dealing with physics and chemistry, with mathematics and mathematical physics, with engineering and instrumentation, and radio propagation. In addition to this major periodical, the Bureau issues another monthly publication called Technical News Bulletin. This is a digest publication designed for technical and trade publications, research, management, and technologists. It summarizes and highlights the current work of Bureau scientists.

The Bureau's Boulder laboratories issue regular basic radio predictions, which are very much like a weather forecast, predicting atmospheric conditions for radio transmission.

In addition to these publications of the Bureau, much information is published in the publications of professional societies. In 1958 the Bureau published 388 articles in professional scientific journals. The Bureau publishes an annual report of its activities. Because of widespread interest last year's report was sold within the first 3 months of issue, and a second edition is presently being considered by the Government Printing Office for reprint. The Bureau's library is one of the finest technical libraries attached to a laboratory. It contains about 80,000 volumes, with approximately 1,700 periodicals, two-thirds of which are foreign country periodicals. The library maintains an exchange program with 46 other nations.

APPENDIXES

Appendix I

Relationship of Present CRPL Program to Space Communications and Space Research

Three of the present CRPL activities are directly related to plans for present or future satellites or space vehicles. One of these is the observation of radio signals received from satellite transmitters. Distortions observed in such signals give both direct information on radio communications possibilities and also information on the medium through which the signals pass. A second program involves a study of the feasibility of mounting a radar sounder in a satellite. Information coming from such a sounder would be telemetered to the ground and provide data on ionization densities in the very high atmosphere. The third direct program involves participation by the IGY World Warning Agency—run by CRPL—in worldwide communications involving the launching and orbit determinations of satellites.

Three other programs involve studies related to the guidance and tracking of satellites and space vehicles. When radio signals travel from a space vehicle to the earth or vice versa, they are refracted or bent by the various layers of the ionosphere. This bending limits the accuracy with which the space vehicle can be tracked or guided. A study of tropospheric refraction and phase stability is providing such information at microwave frequencies. Another program is analyzing regular radio sounder data and preparing special charts to permit the estimation of refractions associated with space vehicle signals. The third program is directly observing the refraction and scintillations of radio noise signals from radio stars which are produced in traversing the atmosphere.

Several more CRPL programs are providing basic physical information concerning the outer fringes of the atmosphere and interplanetary space. A new technique of direct electronic backscatter radar observation is providing information on amounts of ionization and on temperature of the outer fringes of the atmosphere. Observations of whistlers—naturally occurring audio frequency electromagnetic signals—utilize signals which go as much as 10,000 miles out into space and return, giving information on ionization densities in those regions. Studies of naturally occurring VLF emissions are providing information on the interrelation between atomic particles in space and the Earth's magnetic field. Observations of radio noise emitted by the planet Jupiter have provided information on the characteristics of planets other than the Earth. In studying the night airglow, information has been obtained on the zodiacal light which is related to the density of dust particles in interplanetary space. A program on infrared spectroscopy of the high atmosphere is aimed at deducing the concentration of molecular components in that region. And, finally, a study of the number of meteors arriving in the high atmosphere provides some information related to meteoric densities in space.

In addition to the direct research programs, the CRPL is providing advisory services in a number of areas of the space program. Personnel from CRPL hold positions as adviser to the U.S. delegation to the United Nations Ad Hoc Committee on Peaceful Uses of Outer Space, member of the Space Science Board of the National Academy of Sciences, member of NASA Working Group on Satellite Ionospheric Beacons, member of the Working Group on Space Surveillance, Special Committee on Space Technology of NASA, member of Special Committee on Satellites, Office of the Secretary of Defense, member of the Commission on Cosmic-Terrestrial Relationships of the American Geophysical Union, Vice Chairman of the U.S. National Committy for IGY, and member of the (International) Special Committee for the IGY. Several members of CRPL participate in the working groups under the Space Science Board and the panels of the U.S. National Committee for IGY.

Appendix II

Data Processing Systems

The Bureau's program in data-processing systems includes research, development, systems design and analysis, and technical advisory services in both digital and analog computer technology. The Bureau serves Government as a central agency for providing comprehensive and readily available information in both the development and application of high-speed automatic data-processing systems. As a result, a great number of requests are received from other Government agencies for assistance and advice relative to their data processing problems in engineering, management, and operations research, as well as control systems and simulation. These advisory activities strengthen the Bureau's basic computer program, which ranges from research in components, circuits, systems, and simulation to advanced work in new computer applications.

SEAC as a research facility.—The experimental modification, operation, and maintenance of SEAC has been a continuing responsibility. Since it was reoriented from a scheduled scientific computational facility to a research and development tool for new computer systems and specialized areas of application, the memory has been expanded to 2,048 words to facilitate tryouts of larger-volume data-processing problems. During the past year, provision was made for parallel input-output with alphanumerical representation, and for handling information from the analog computer. A high-speed photoelectric paper tape reader and punch were incorporated in the system. Testing of the versatile high-speed multichannel magnetic tape system for parallel input and output is in process.

Analog computers.—The analog computer is an additional facility for the solution of problems in connection with the Bureau's scientific programs and also an important part of the simulation facility for solving various problems in simulation of physical systems. It was augmented by two new GEDA function generators and one 6-amplifier summing unit. For the large X–Y plotter, an rf pickup was procured, simplified modal conversion was arranged, and a sampled-data smoother was designed and constructed.

Pilot electronic data processor.—The system design plans for the new NBS pilot electronic data processor are now virtually completed, and the engineering necessary for its physical construction is underway. This general-purpose system is suited to the processing of digital information at very high speed, and when completed is to be utilized for experimental investigations on a wide variety of large-scale problems of special importance to the Government.

To enable the machine to be used as a research tool for such varied purposes, the system was designed to include a number of different characteristics that are not ordinarily associated with one machine, such as high computation rate, flexibility of communication with the outside, and a wide variety of internal operations. The system contains three independently operating computers, each of which is specially adapted for performing certain special classes of operations that frequently occur in large-scale data-processing applications. The system thus provides a working model of an integrated multiple-computer network.

Components and techniques.—Under the sponsorship of the Air Force Cambridge Research Center, instruments were constructed to perform measurements on samples of new switching transistors; transitorized read, write, and control circuits for magnetic tape input-output searching systems were developed, and the transitorized diode-capacitor memory was tested. In addition, work on the d-c stability and drive capabilities of an Eccles-Jordan transistor flip-flop, and on the development of a high-speed or inverter circuit was completed. Studies were made on the measurement and equivalent circuit characterization of diffused transistors at very high frequencies and large signals to establish a basis for predicting accurately the performance of high-speed switching circuits. Samples of new types of switching transistors and related components were procured and tested. Characteristics of these commercially available transistors were then coded and punched into cards to facilitate selecting those types satisfying given specifications.

A trapped-flux memory using evaporated superconducting films was studied. In addition to basic studies in superconductivity, photo-resist techniques in forming tiny intricate masks for multilayer evaporations were investigated. Work continued on the study of evaporated ferromagnetic films for uses as elements in a coincident current memory array.

Under the sponsorship of the Office of Naval Research, studies were made on transistor nor-circuit design the design of a parallel adder with nor-circuits, and some aspects of the theory of asynchronous circuits.

Transistor-magnetic core circuitry.—The transistor-magnetic core circuitry, developed under the sponsorship of the Department of Defense. was refined and completed during the year. Circuits were specificially designed to perform the logical and switching functions of the central portion of a digital computer. Three basic packages, for gating, pulse repeating, and complementing, were designed to perform all required computing functions, and with these modules a small system was designed for testing the overall operating margin of an array of the packages. The results to date have shown highly reliable operation.

Rapid selector.—Under the joint sponsorship of the Patent Office and the Bureau of Ships, the rapid selector, originally designed by Yale University, was completely redesigned, using computing techniques. This development is intended to retrieve rapidly information from massive files of correspondence, drawings, patents, and similar matter which has been transferred to 35-millimeter film. Its optical and mechanical systems were improved and the detecting and related electronic interrogating system was redesigned. As a realistic testing ground for the device, a master film using articles from the NBS "Technical News Bulletin" series was prepared using a high-efficiency coding system. The present laboratory prototype is being tested to determine the reliability of the modified circuitry.

Digital systems research.—Research on the problem of using an existing computer to work out the design details for a new and more advanced computer has reached the point where a large-scale practical test can now be run. A complete procedure was formulated for mechanizing the work of converting system design plans into printed tables that specify the exact point-to-point wiring interconnections and other detailed data needed for constructing an actual machine. To provide a rigorous practical test of this procedure, it is currently being employed to convert the system design plans of the new NBS pilot electronic data processor into fabrication data for constructing the new machine.

An investigation of the problem of harnessing several computers into a network of machines is now underway to try to meet the extreme requirements in computing speed and data storage that many important future computer applications will demand. Since such requirements are beyond the capabilities of any single machine using currently available technology, methods must be developed for organizing several machines to work cooperatively on a common task. The initial investigation was directed toward evaluating the efficiency of several schemes by which the independent computers in the network can share a common workload. Various models were devised for simulating the behavior of pairs of computers working together and exchanging information, and their relative operating efficiencies were calculated. A number of automatic control schemes were devised for solving the problem of interlocking a pair of computers, and one of these schemes was chosen for use in the system of the NBS pilot electronic data processor.

Advanced computer systems.—Technical advice and assistance were provided to the Aberdeen Proving Ground's Ballistic Research Laboratories on the design of the BRL digital computing and data-processing installation. Specifications were formulated for various multipurpose calculating and processing units in the BRL system, and detailed logical diagrams were devised. Assistance was also given on the specification and procurement of component packages and high-speed magnetic-core memory units.

Appendix III

Building Technology

The Bureau conducts research in the fields of chemistry, physics, and engineering to assist the building industry in making advantageous use of scientific knowledge and techniques. It also assists other Government agencies in solving special technical building problems. Research emphasis is directed toward increasing knowledge about the factors affecting the performance of buildings, their facilities and equipment, the behavior of structures under various conditions, and the nature of the physical processes that result in changes in materials in different environments. Much of the data are used in the development of specifications and standards prepared by technical organizations, and in manuals of design

During the year significant improvements were made in the precision of measurements of the thermal conductivity of metals over the range −150° to 750° C; a new technique was developed for determining the self-ignition properties of materials; substantial progress was made in developing methods of testing and new design criteria for underground insulated pipe; further progress was made in developing methods for separating asphalts into their components and in applying chromatographic and spectrometric techniques to studies of the chemical and physical processes of asphalt deterioration; and a contribution was made to a better understanding of the mechanisms of diagonal tension failures of reinforced concrete structures.

Fire hazards of common combustible materials.—Because of the complexity of the behavior of fires and the lack of understanding of the mechanisms of either the growth or the inhibition of fires, only arbitrary methods for measuring the fire hazard properties of materials have been available. However, significant progress was made during the past year in measuring the ignition properties of solids and liquids by means of an adiabatic furnace. The kinetic reaction constants measured in this manner can be used for predicting the size of pile and the ambient temperature which may be considered safe for the storage of combustible material over prolonged periods. Such information is of value not only to manufacturers and others concerned with transporting and stockpiling ordinary materials, but could help determine safe conditions for storing rocket fuels and explosives.

Fire retardants for fabrics.—A study of the effectiveness of five fire-retardant treatments for fabrics was completed, and the methods used for measuring retardancy were reconsidered.

Fabrics studied included cotton and rayon textiles of various weaves and color. Although they provided a considerable range in finish and weight, four of the five fabric samples were considered well suited for fire-retardant treatments. Of the seven different treatments applied to the fabrics, all tended to stiffen the fabrics, some slightly, others severely. A simple water-soluble treatment was as effective a fire retardant as any, but other treatments tended to retain their effectiveness better after laundering. The data disclosed not only lack of concordance between the results of flame resistance tests made by different methods but also the need for research to develop better methods to measure the fire hazard properties of fabrics.

Standards for refrigerated trailers.—A method for determining the cooling load of refrigerated trailers is currently under study in a program sponsored by the Truck-Trailer Manufacturers' Association, the U.S. Department of Agriculture, and the Quartermaster Research and Engineering Command. The objective is to develop a standard laboratory rating method that can be applied to refrigerated semitrailers under simulated road conditions. At present no standards exist for rating truck and trailer bodies for heat transfer, moisture gain, and air leakage, nor for rating the refrigerating units that cool them. Insulated bodies and refrigerating units are matched largely by empirical rules even though this type of transportation represents a $100 million a year industry.

The importance of air leakage and moisture transfer on a total cooling load was shown by comparative laboratory and road tests. The pathways and mechanisms of air and moisture movement appeared to be controlled principally by the air pressure pattern produced around the body when in motion. The proposed rating procedure consists of a laboratory measurement of the steady state heat transfer rate of a trailer, determined while the interior is maintained at 0° F, the ambient conditions are 100° F dry bulb temperature and 50 percent relative humidity, and with a static air pressure on the nose of the trailer simulating the ram air pressure at a road speed of 50 miles per hour.

Underground pipe insulation.—For the past several years the Bureau has been studying methods for insulating underground steam and hot water distribution systems under the sponsorship of the Office of the Chief of Engineers, the Bureau of Yards and Docks, and the Air Force. The investigation is intended to provide data on the insulating properties, water permeance, expansion characteristics, and chemical and mechanical stability of insulating materials and on the principles of simultaneous heat and moisture transfer in insulating materials and soils under simulated service conditions. Although this project is not yet completed, sufficient data and information have been gathered to serve as a basis for tentative criteria to design a good protective system for underground heat distribution piping. These criteria were used by various Federal agencies as the basis for writing new specifications that will be essentially uniform in their requirements.

Conductive flooring in danger areas.—Sparks resulting from the accumulation of static electricity constitute a danger when explosive vapors are present. An

effective means of mitigating this hazard lies in keeping the electrical resistance between objects in the hazardous location so low that dangerous sparking potentials are never attained. Most objects normally rest or move upon the floor and therefore can be electrically connected by way of the floor if it has sufficient electrical conductance.

In cooperation with agencies of the Department of Defense, all types of conductive flooring materials recommended for use in hospital operating suites were evaluated in the laboratory and in the field. This included investigating instruments and methods pertinent to the testing of conductive flooring. A report on electrical and nonelectrical properties, and a proposed purchase specification were prepared for eight types of electrically conductive flooring materials.

Degradation of asphalt.—In the course of the Bureau's studies of the mechanism of asphalt degradation this year, asphalts were separated into their components and the components were weathered separately and in different combinations. Changes due to weathering were observed by infrared spectrometric and other techniques, and a technique was developed for taking infrared spectra of whole asphalts, using films from 1 to 2 mils in thickness.

The effect of a number of antioxidants on the weight losses and durabilities of asphalts exposed to accelerated weathering was determined, and a study of the relationship between the physical properties and component distribution of an asphalt during the blowing operation showed that the softening point and asphaltene content increased linearly with the time of blowing. Other work indicated that of two asphalts having essentially the same physical characteristics the one with the lower asphaltene content had the greater durability on exposure to the weather.

Strains in reinforced concrete beams having diagonal cracks.—In cooperation with the American Iron and Steel Institute, beams of unusually small ratios of span to depth were investigated when loaded to cause failures by diagonal tension. Numerous measurements of strains showed that, after the formation of the typical diagonal cracks, the maximum longitudinal compressive strains occurred between the extreme fiber and the neutral surface rather than at the extreme fiber as predicted by theory. This result implies distortions of sections that were originally plane. The strains also indicate that longitudinal reinforcement of large bars resists a significant part of the external shear after the formation of a diagonal crack. However, the shearing force in the bars decreased rapidly as the load approached the maximum, and the evidence available indicates that the shearing resistance is not of practical significance except for beams of unusually small ratio of span to depth.

Drying shrinkage of concrete masonry units.—To develop an improved, rapid method of determining the drying shrinkage of concrete masonry that indicates the potential shrinkage under service conditions, a study was made of the shrinkage characteristics of concrete units. Tests on autoclaved and low-pressure cured blocks of several different aggregates showed that the shrinkage may be determined rapidly at room temperature by the use of thin laminas removed from concrete units at right angles to the face shell. The shrinkage of the thin laminas correlates well with that of the control specimens of full-size blocks under the same exposure conditions.

Appendix IV

Cryogenic Engineering

The Bureau's cryogenic engineering program, located at the Boulder laboratories, is designed to provide information for the practical application of very low temperatures to both Government and industry faced with problems in this rapidly growing specialized field.

To carry out these objectives, research is conducted on the properties of materials at low temperatures, on cryogenic processes, and on cryogenic equipment. The demand for advisory services by both industry and other Government agencies has greatly increased as a result of rapidly accelerated programs dealing with long-range missiles and space vehicles. All vehicles that are now in service and most of those planned utilize low-temperature liquids as propellants. A noteworthy example is the nuclear powered rocket now under development which will be propelled by liquid hydrogen.

Low-temperature liquids.—The Bureau conducted investigations into the use of liquid oxygen in a missile tank concentrating on instrumentation for the accurate determination of the amount of liquid oxygen aboard during standby, miscella-

neous heat-transfer problems connected with transferring the liquid oxygen to the missile, the generation of electrostatic charge during transfer, and the effect of violent vibrations on the liquid oxygen.

Other work included the design of cryogenic equipment, such as the helium liquefier which was put into operation during the past year. The liquefier is providing enough liquid helium to meet all the present requirements of the Boulder laboratories as well as 45 to 50 liters per week for use in free radical research at the Washington laboratories. Another piece of apparatus completed is a distillation column used to study the feasibility of separating deuterium from ordinary hydrogen. This distillation column is expected to provide valuable data to designers of large-scale equipment for producing deuterium or heavy water.

Cryogenic engineering data.—To make generally available the techniques of cryogenics to engineers and other research workers, a book on the subject of cryogenic engineering is under preparation. In a further effort to meet the demand for technical information a Cryogenic Engineering Data Center was established. The center is compiling an organized index of published literature applicable to the cryogenic engineering field.

Flow of liquefied gases.—Single-phase liquefied gas flow studies consisted of theoretical analyses aimed at providing a basis for designing long transfer systems in which single-phase fluid flow could be maintained. Two-phase flow work was confined to experiments planned to provide a basis for the design of transfer systems in which both liquid and vapor phases are present. This work showed that the pressure drop in steady, two-phase, single-component fluid flow can be predicted from the Lockhart and Martinelli correlation if simple corrections are made to account for changes in the axial component of momentum.

Both theoretical and experimental work was performed to evaluate the behavior of sharp-edged orifices as flow meters for liquefied gases. The experimental work indicates that these devices can be used with confidence with cryogenic liquids as long as pure liquid enters the device—a limitation common to all volumetric flow meters. The theoretical work was designed to predict the discharge coefficients which were obtained empirically before. Results obtained thus far appear to account for previously unexplained observations.

Storage of liquefied gases.—Several innovations in the design of mobile containers for liquefied gases were incorporated in a liquid oxygen container for the Wright Air Development Center. This container has a predicted heat leak which may be as little as one-quarter that of present containers for similar applications. Its successful storage ability results from such design considerations as the utilization of the load-bearing qualities of evacuated powder insulation and the use of plastic materials for support members.

A cryostat, developed for the Air Force Cambridge Research Center, maintains a superconducting resonator at liquid helium temperature for over 40 days without service or maintenance of any kind. One of the novel features of this cryostat is a mechanism which permits the tuning at any time of the resonating cavity from outside the cryostat.

Experimental work during the development of vacuum-insulated transfer lines for liquid nitrogen demonstrated the feasibility of using "condensing type" vacuum insulation. The advantage of this system is that vacuum-insulated equipment may have long shelf life even though it contains leaks which would ruin conventional vacuum (Dewar) insulation. This work was undertaken with the support of the Rocket engine Test Station, Edwards Air Force Base, Calif.

Hydrogen refrigerator for bubble chamber.—For the past 3 years assistance has been given to the University of California Radiation Laboratory in the development of liquid hydrogen bubble chambers. Liquid hydrogen refrigeration is required for continuous operation of the bubble chamber. During the past year an 1,800-watt hydrogen refrigerator was built in accordance with basic NBS designs. It will soon be assembled as part of the bubble chamber unit at UCRL.

From this work resulted a new procedure for use in the design of high-pressure heat exchangers of the type usually employed in low-temperature processes. An effort was made to balance the flow and therefore increase the efficiency in a given heat transfer area. Results of refrigerator performance tests gave initial verification to the new design procedures.

Helium liquefaction.—In giving assistance to the Navy Bureau of Aeronautics in its plan for the liquefaction and distribution of helium, the best designs possible were made of liquid helium containers in sizes ranging from light, transportable units to large road-transportable trailers and rail tank cars. Weight and no-loss storage time were the primary considerations of these design optimizations. Studies of helium gas liquefaction processes that were made during past years

are now being used by the sponsor and by the U.S. Bureau of Mines in the procurement of liquefaction facilities.

Low temperature properties of materials.—It is well known that certain of the austenitic stainless steels (300 series) partially transform to martensite on chilling, especially if they have been cold-worked. Because of the widespread use of these steels in cryogenic equipment, it was desirable to study an unexplored aspect of this transformation, namely its slow continued occurrence during long exposure to a constant low temperature. Magnetic analysis is being used to investigate the occurrence of such changes.

In the course of the Bureau's program of measuring mechanical and thermal properties useful in low-temperature engineering and research, determinations of the ultimate, tensile, yield, and impact strengths of a group of commercial magnesium alloys were made. These measurements indicate that these alloys have only limited special uses in cryogenics because of their low impact strengths. Investigations of a relatively new aluminum alloy of promising characteristics showed that deformation at slow strain rates occurs by repeated sudden yielding. Ultimate and tensile strength, shear modulus, and Young's modulus were measured on a group of plastic foams. These properties together with the thermal expansion coefficient are sufficient to determine the ability of bonded foam insulations to withstand thermal stress.

The thermal conductivities of two copper-silver alloys were measured. These, with the high-purity copper measured earlier, formed an alloy series with graded silver content. Separation of the ideal and defect thermal resistivities for each sample showed a new effect, the existence of a residual term representable as a cross product of the two resistivity components, as was predicted theoretically by Sondheimer.

Tentative temperature-electromotive force reference tables for gold-cobalt versus copper, gold-cobalt versus silver-gold, and copper versus constantan thermocouples were derived from experimental measurements down to 4° K. These thermocouples are important as practical low-temperature thermometers of moderate accuracy.

Gas liquefaction.—This was a record year in the production of liquefied gases. Nearly 200,000 liters of 90 to 95 percent parahydrogen were liquefied, and over a million liters of liquid nitrogen and 2,500 liters of liquid helium were produced. In addition, some 65,000 standard cubic feet of pure hydrogen gas and about 200,000 cubic feet of pure nitrogen gas were produced for both laboratory and offsite use. Cryogenic fluids were furnished to Bureau laboratories for applied research and engineering development, to other government agencies and their contractors in the area, and to private companies and institutions.

The general practice of recovering hydrogen gas evaporated during storage, handling, and on-site use of the liquid netted almost 3 million cubic feet of gas for reuse in liquefaction. This nearly equaled the amount of electrolytic gas purchased, and made possible some of the large runs that would otherwise have exceeded local available supply. Gas recovery from offsite use will be considered if substantial increase in requirements materialize. This practice also reduces operating costs, since in large production the cost of the gas is a major item of liquefaction cost.

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